Tropical Biomedicine 39(1): 78-85 (2022)
https://doi.org/10.47665/tb.39.1.018

RESEARCH ARTICLE

Descriptions of adults of *Simulium* (*Gomphostilbia*) *sachini* Takaoka & Henry and *S.* (*G.*) *williei* Takaoka & Thapa in the *S.* (*G.*) *gombakense* species-group (Diptera: Simuliidae) from India

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ARTICLE HISTORY

Received: 12 February 2022
Revised: 7 March 2022
Accepted: 7 March 2022
Published: 31 March 2022

ABSTRACT

The *Simulium gombakense* species-group, one of the 15 species-groups of the subgenus *Gomphostilbia* Enderlein, is small, being represented by only 12 species, all of which are distributed in the Oriental Region. It is characterized by the pupal gill composed of an inflated structure and eight or ten slender filaments. Among the 12 species, *S. sachini* Takaoka & Henry, and *S. williei* Takaoka & Thapa were originally described from two pupae, and one pupa and two larvae, respectively, from Darjeeling, India. In the present paper, the adult females and males of these species are described for the first time from specimens reared from pupae collected at the type locality. *Simulium sachini* is distinctive in the female by the claw with a medium-sized basal tooth, and in the male by the somewhat enlarged, spindle-shaped hind basitarsus and ventral plate with its ventral margin much depressed medially, while *S. williei* is characterized by the small number of male upper-eye (large) facets in 12 vertical columns and 13 or 14 horizontal rows and ventral plate much produced posteroventrally. Taxonomic notes are given to separate these two species in the adult stage from their related species.

Keywords: Black fly; Simuliidae; taxonomy; Oriental Region.

INTRODUCTION

The *Simulium gombakense* species-group, one of the 15 species-groups of the subgenus *Gomphostilbia* Enderlein, defined by Takaoka (2012), is small, being represented by only 12 species, which are distributed from Hong Kong and Hainan Island in the east to Nepal in the west through Vietnam, Thailand, Peninsular Malaysia, Myanmar and India (Adler, 2021). The species in this group are easily identified by the specific configuration of their pupal gill composed of an inflated structure and eight or ten slender filaments (Takaoka, 2012).

The biting habits and other biological aspects of these species are unknown, although one female of *S. aziruni* Takaoka, Hashim & Chen was captured while flying around a human in Peninsular Malaysia (Izwan *et al*., 2021).

Among the 12 species in the *S. gombakense* species-group, *S. sachini* Takaoka & Henry and *S. williei* Takaoka & Thapa were originally described from two pupae, and one pupa and two larvae, respectively, from Darjeeling, India (Takaoka *et al*., 2010). The male and mature larva of *S. sachini* were subsequently described based on specimens from Nepal (Takaoka & Shrestha, 2010).

In the present study, we describe the adult females and males of these two species for the first time, based on specimens from the type locality (Darjeeling, India), and characterize them relative to related other species.

MATERIAL AND METHODS

Two females and two males of *S. sachini* and two females and two males of *S. williei* were used for morphological observation and descriptions. All adults were reared from pupae collected from a small stream (width 12–13 cm, depth 2–3 cm, 15–16°C, shaded, elevation 2,354 m, 27°23’25.3”N, 88°25’68.5”E) (type locality) at Dali, Darjeeling, India, 28-VII-2010, by S. Thapa. All specimens were fixed in 80% ethanol.

The methods of collection, description and illustration, and terms for morphological features, follow those of Takaoka (2003) and partially those of Adler *et al*. (2004).

All specimens used are deposited in the Entomology Section of the Queen Sirikit Botanic Garden, Chiang Mai, Thailand.

RESULTS AND DISCUSSION

***Simulium* (*Gomphostilbia*) *sachini* Takaoka & Henry, 2010**

Description. Female (n = 2). Body length 2.5 mm. ***Head***. Slightly narrower than width of thorax. Frons dark brown, densely covered with whitish-yellow scale-like recumbent short hairs interspersed with few dark longer hairs along each lateral margin; frontal ratio 1.58–1.65:1.00:1.97–2.00; frons:head ratio 1.00:4.44–4.48. Fronto-ocular area well developed, narrow, directed dorsolaterally. Clypeus dark brown, densely covered with whitish-yellow scale-like hairs interspersed with several dark longer hairs on each side. Labrum 0.69–0.75 times length of clypeus. Antenna composed of scape, pedicel and nine flagellomeres, dark brown except scape, pedicel and base of first flagellomere yellow. Maxillary palpus composed of five segments, light to medium brown, proportional lengths of third, fourth, and fifth segments 1.00:0.96:1.84–1.98; sensory vesicle (Figure 1A) ellipsoidal, medium-long (0.38–0.44 times length of third palpal segment), with medium-sized opening. Maxillary lacinia with 10–13 inner and 15–17 outer teeth. Mandible with 25–29 inner teeth and 10–14 outer teeth (beginning from tip). Cibarium (Figure 1B) medially forming sclerotized plate folded forward from posterior margin, with weakly sclerotized mediolongitudinal ridge with dark bifid apex. ***Thorax***. Scutum medium to dark brown except anterolateral calli ochreous, with three faint longitudinal vittae (one median and two submedian), densely covered with whitish yellow scale-like recumbent short hairs. Scutellum light brown, covered with whitish yellow short hairs and dark brown long upright hairs along posterior margin. Postnotum medium brown, and bare. Pleural membrane ochreous and bare. Katepisternum longer than deep, medium brown, shiny when illuminated at certain angles, moderately covered with fine yellow and brown short hairs. ***Legs***. Foreleg: coxa whitish yellow; trochanter light brown except base whitish yellow; femur light to medium brown with apical cap dark brown; tibia yellow except apical three-tenths dark brown, and outer surface widely whitish; tarsus dark brown, with moderate dorsal hair crest; basitarsus moderately dilated, 5.58–6.26 times as long as its greatest width. Midleg: coxa medium brown except posterolateral surface dark brown; trochanter light brown; femur light to medium brown with apical cap dark brown; tibia whitish yellow on basal one-third and light to dark brown on rest; tarsus medium to dark brown except basal half of basitarsus dark yellow to light brown. Hind leg: coxa medium brown; trochanter light brown; femur light to medium brown with apical cap dark brown; tibia (Figure 1C) yellowish white on basal half, and light to dark brown on rest; tarsus (Figure 1D) dark brown except basal seven-tenths or little less of basitarsus (though base light brown) and basal half of second tarsomere yellowish white; basitarsus narrow, nearly parallel-sided, though slightly narrowed apically, 6.25–6.55 times as long as wide, and 0.63–0.73 and 0.54–0.59 times as wide as greatest widths of tibia and femur, respectively; calcipala slightly longer than width at base, and 0.56 times as wide as greatest width of basitarsus; pedisulcus well developed; claw (Figure 1E) with medium-sized basal tooth 0.38 times length of claw. ***Wing***. Length 2.4 mm. Costa with dark spinules and hairs except basal patch of yellow hairs. Subcosta with dark hairs except near apex. Base of radius with tuft of yellow hairs. Basal portion of radius fully haired; R_1 with dark spinules and hairs; R_2 with hairs only. Basal cell absent. ***Halter***. White except basal portion darkened. ***Abdomen***. Basal scale yellow, with fringe of whitish yellow hairs. Dorsal surface of abdomen dark brown to brownish black except basal two-thirds ochreous, moderately covered with dark short to long hairs; tergites of segments 2 and 6–9 shiny when illuminated at certain angles. Sternal plate on segment 7 undeveloped. ***Terminalia***. Sternite 8 (Figure 1F) bare medially, with 20–26 medium-long to long hairs together with three to five slender short hairs on each side. Ovipositor valves (Figure 1F) triangular, thin, membranous, each moderately covered with microsetae interspersed with two or three short hairs; inner margins nearly straight or sinuous, somewhat sclerotized, and moderately separated from each other. Genital fork (Figure 1G) of usual inverted-Y form, with slender stem; arms of moderate width, much folded medially, and with short projection directed posteromedially. Paraproct in ventral view (Figure 1H) nearly triangular, with four or five sensilla on anteromedial surface; paraproct in lateral view (Figure 1I) somewhat produced ventrally beyond ventral tip of cercus, 0.73 times as long as wide, with 14–16 medium-long to long hairs on ventral and lateral surfaces. Cercus in lateral view (Figure 1I) short, rounded posteriorly, 0.58 times as long as wide. Spermatheca (Figure 1J) ellipsoidal, 1.48–1.52 times as long as its greatest width, well sclerotized and darkened except duct and small area near juncture with duct unpigmented, and with many fissures on outer surface; internal setae absent; both accessory ducts unpigmented, slender, slightly thicker in diameter than major one.

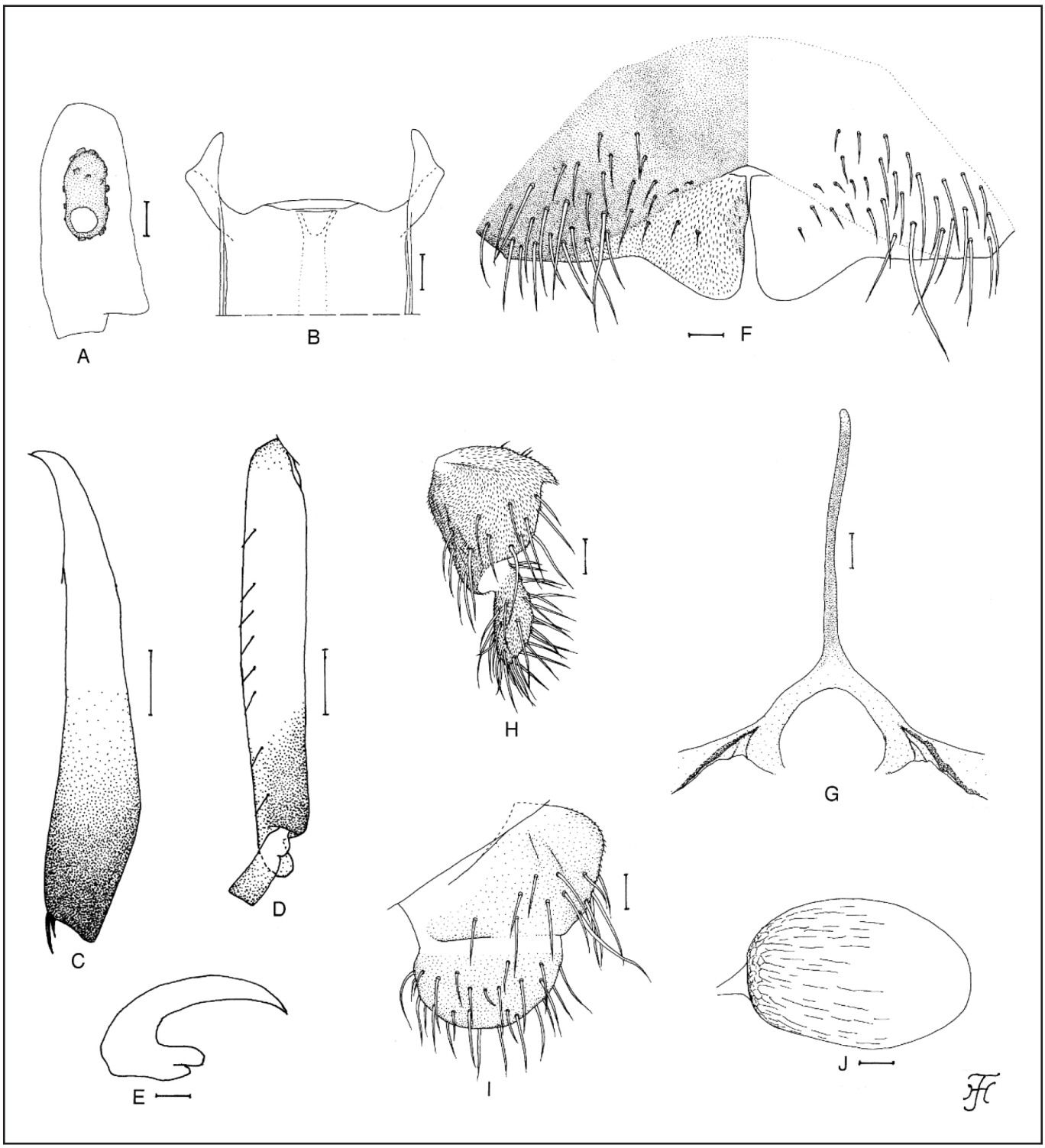

Figure 1. Female of *S. sachini.* A, sensory vesicle (right side; front view). B, cibarium (front view). C, hind tibia (left side; outer view). D, hind basitarsus and second tarsomere (left side; outer view). E, claw. F, sternite 8 and ovipositor valves (ventral view). G, genital fork (ventral view). H & I, paraprocts and cerci (right side; H, ventral view; I, lateral view); J, spermatheca. Scale bars. 0.1 mm for C and D; 0.02 mm for A, B and F–J; 0.01 mm for E.

Male (n=2). Body length 2.2–2.3 mm. ***Head***. Nearly as wide as thorax. Upper eye medium brown, consisting of large facets in 16 or 17 vertical columns and 17 or 18 horizontal rows on each side. Clypeus brownish black, whitish pruinose, densely covered with yellow scale-like medium-long hairs (mostly directed upward) interspersed with several dark brown longer hairs near lower margin on each side. Antenna composed of scape, pedicel and nine flagellomeres, medium to dark brown except scape and pedicel yellow and base of first flagellomere whitish yellow, though apical half of pedicel often light to medium brown; first flagellomere elongate, 1.57–1.67 times length of second. Maxillary palpus light to medium brown, with five segments, proportional lengths of third, fourth, and fifth segments 1.00:1.20–1.21:2.37–2.79; third segment (Figure 2A) slender, widened apically; sensory vesicle (Figure 2A) small, ellipsoidal (0.22–0.28 times length of third segment), and with small opening. ***Thorax***. Nearly as in female. ***Legs***. Nearly as in female except fore basitarsus slightly dilated, 7.26 times as long as its greatest width; hind tibia light to dark brown except basal one-fifth yellow; hind basitarsus (Figure 2B) medium to dark brown except basal half dark yellow to light brown, moderately enlarged, spindle-shaped, 4.00 times as long as wide, and 0.82 and 0.85 times as wide as greatest width of tibia and femur, respectively; calcipala (Figure 2B) nearly as long as basal width, and 0.33 times as wide as greatest width of basitarsus; pedisulcus well developed. ***Wing***. Length 2.2–2.3 mm. Other characters as in female except subcosta bare. ***Halter***. Dull white except basal stem darkened. ***Abdomen***. Basal scale ochreous, with fringe of light brown hairs. Dorsal surface of abdomen medium brown to brownish black except basal half of segment 2 ochreous, covered with dark brown short to long hairs except parts of segment 2 with yellowish hairs; segments 2 and 5–8 each with pair of shiny dorsolateral or lateral patches. ***Genitalia***. Coxite in ventral view (Figure 2C) nearly rectangular, 1.85 times as long as its greatest width. Style in ventral view (Figure 2C) bent inward, with single apical spine; style in ventrolateral view (Figure 2D) moderately tapered from base to middle, then slightly tapered toward round apex, 0.86 times length of coxite and 2.56 times as long as its greatest width at base. Ventral plate in ventral view (Figure 2C) with body transverse, 0.54 times as long as wide, widened posteriorly, with anterior margin produced anteromedially, posterior margin moderately concave medially, and moderately covered with microsetae on ventral surface; basal arms of moderate length, nearly parallel-sided or slightly divergent, then moderately convergent apically; ventral plate in lateral view (Figure 2E) moderately produced ventrally; ventral plate in caudal view (Figure 2F) with ventral margin greatly concave medially, and moderately covered with microsetae on posterior surface except dorsolateral portions bare. Median sclerite arising near anterior tip of ventral plate (Figure 2E) and broad, plate-like in caudal view (Figure 2G). Paramere (Figure 2H) of moderate size, with one distinct long, two medium-long and several short hooks. Aedeagal membrane (Figure 2I) densely setose; dorsal plate not defined. Ventral surface of abdominal segment 10 (Figure 2J, 2K) without distinct hairs near posterolateral corners. Cercus (Figure 2J, 2K) small, with 17–19 hairs.

Remarks. The female of *S. sachini* is characterized by the claw with a medium-sized basal tooth 0.38 times as long as the claw (Figure 1E), a rare characteristic among species of the *S. gombakense* species-group. Only *S. aziruni* Takaoka & Chen from Peninsular Malaysia (Ya'cob *et al*., 2019) has such a medium-long basal tooth on the claw (0.4 times as long as the claw), and females of the other species of this species-group have the claw with a large basal tooth 0.48–0.53 times as long as the claw, although the females of three other species of the *S. gombakense* species-group are unknown. The female of *S. sachini* is distinguished from *S. aziruni* by the relative width of the head against the greatest width of the frons (4.4–4.5 in *S. sachini* versus 5.7 in *S. aziruni*) and lack of a dark subbasal marking on the hind tibia.

The male, redescribed based on specimens from the type locality in India, shows that most of the male characteristics of *S. sachini* are the same as previously described based on specimens from Nepal (Takaoka & Shrestha, 2010).

The male of *S. sachini* is characterized by the greater number of upper-eye (large) facets in 16 or 17 vertical columns and 17 or 18 horizontal rows, hind basitarsus spindle-shaped, somewhat enlarged, 4.0 times as long as its greatest width (Figure 2B), and ventral plate with a ventral margin deeply concave when viewed posteriorly (Figure 2F). Only two other species, *S. maleewongae* Takaoka, Srisuka & Saeung from Thailand (Takaoka *et al*., 2016) and *S. nuwakotense* Takaoka & Shrestha from Nepal (Takaoka & Shrestha, 2010), have such a unique shape of the ventral plate. The ventral plate is flat or produced ventrally to a varying extent in most species of the subgenus *Gomphostilbia*. Of these two species, the male of *S. nuwakotense* is almost indistinguishable from that of *S. sachini* in sharing many characteristics including the number of upper-eye (large) facets, relative length of the fore basitarsus against its greatest width, and spindle-shaped hind basitarsus, although the relative width of the hind basitarsus against the hind femur is somewhat different (0.75 in *S. nuwakotense* versus 0.85 in *S. sachini*). The male of *S. sachini* is distinguished from *S. maleewongae* by the greater number of upper-eye (large) facets in 16 or 17 vertical columns and 17 or 18 horizontal rows (15 vertical columns and 15 horizontal rows in *S. maleewongae*).

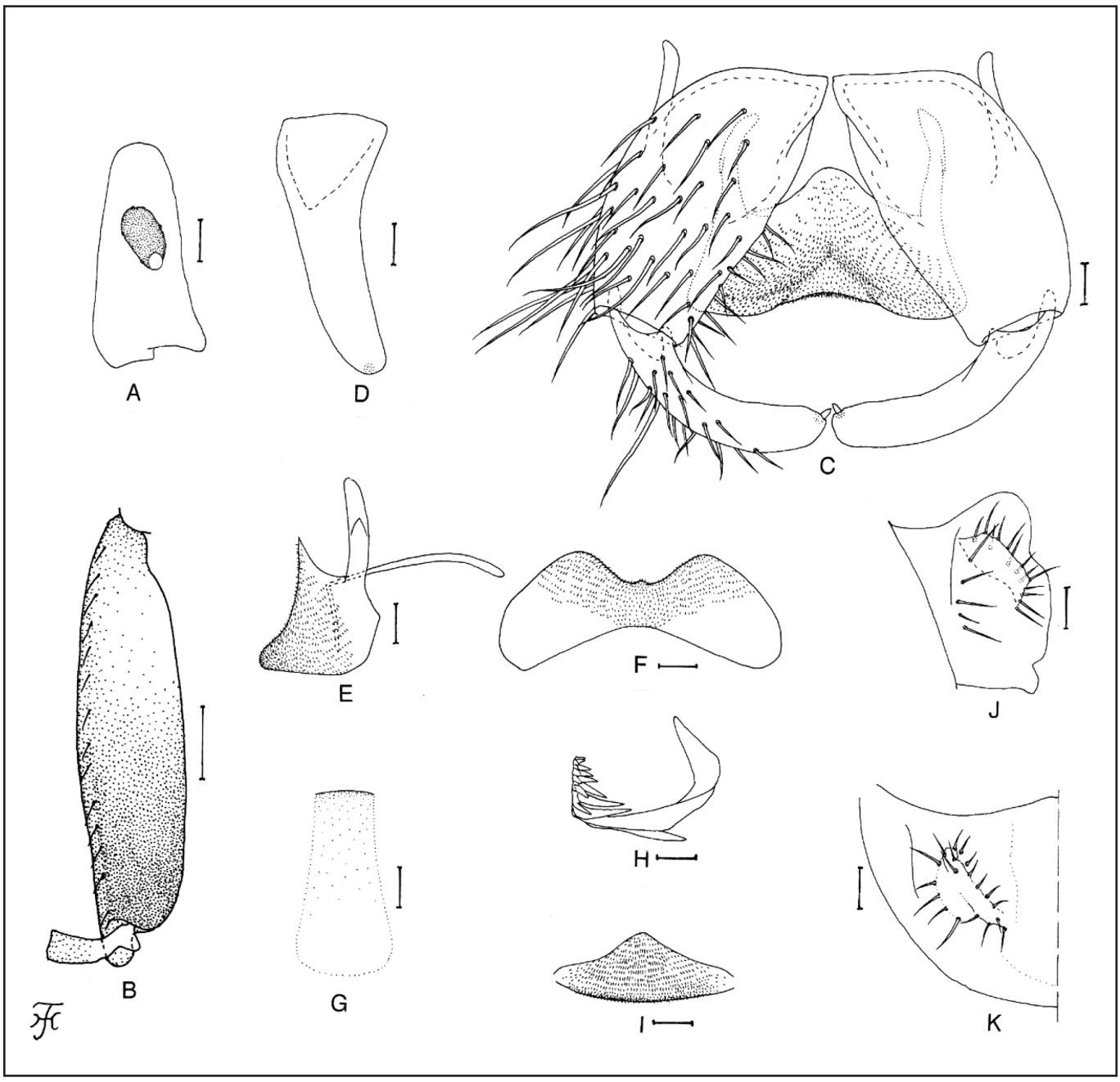

Figure 2. Male of *S. sachini*. A, sensory vesicle (right side; front view). B, hind basitarsus and second tarsomere (left side; outer view). C, coxites, styles and ventral plate (ventral view). D, style (right side; ventrolateral view). E, ventral plate and median sclerite (lateral view). F, ventral plate (caudal view). G, median sclerite (ventral view). H, paramere (right side; dorsal view). I, aedeagal membrane (caudal view). J and K, 10th abdominal segments and cerci (right side; J, lateral view; K, caudal view). Scale bars. 0.1 mm for B; 0.02 mm for A and C–K.

***Simulium* (*Gomphostilbia*) *williei* Takaoka & Sachin, 2010**

Description. Female (n = 2). Nearly as in female of *S. sachini* except following characteristics. Body length 2.3 mm. ***Head***. Frontal ratio 1.57–1.84:1.00:2.07–2.24; frons:head ratio 1.00:4.03–4.31. Labrum 0.54–0.64 times length of clypeus. Maxillary palpus: proportional lengths of third, fourth, and fifth segments 1.00:1.05–1.08:2.05–2.23; sensory vesicle (Figure 3A) ellipsoidal, medium-long (0.41–0.45 times length of third palpal segment), with medium-sized opening. Maxillary lacinia with 10–15 inner and 16–21 outer teeth. Mandible with 34–37 inner teeth and 10 or 11 outer teeth (beginning from tip).

Legs. Foreleg: coxa and trochanter whitish yellow; femur dark yellow to light brown with apical cap medium brown (though extreme tip yellowish); tibia dark yellow to light brown with base yellow, apical cap medium brown, and outer surface widely paler; tarsus dark brown, with moderate dorsal hair crest; basitarsus moderately dilated, 5.58–6.52 times as long as its greatest width. Midleg: coxa medium brown except posterolateral surface dark brown; trochanter yellow; femur dark yellow to light brown with base yellow and apical cap medium brown (though extreme tip yellowish); tibia whitish yellow on basal one-third and light to medium brown on rest; tarsus medium brown. Hind leg: coxa yellow; trochanter whitish yellow; femur dark yellow to light brown with base whitish yellow and apical cap medium brown (though extreme tip yellowish); tibia light brown except basal one-fourth to one-third whitish yellow and apical cap dark brown; tibia densely covered with whitish yellow hairs on basal three-fourths of lateral and posterior surface; tarsus (Figure 3C) light to medium brown except basal five-sixths (though base light brown) and basal half of second tarsomere yellowish white; basitarsus narrow, nearly parallel-sided, though slightly narrowed apically, 6.12–6.19 times as long as wide, and 0.67–0.77 and 0.55–0.57 times as wide as greatest width of tibia and femur, respectively; calcipala nearly as long as width at base, and 0.47 times as wide as greatest width of basitarsus; claw (Figure 3E) with large basal tooth 0.52 times length of claw. ***Wing***. Length 2.2 mm. ***Abdomen***. Dorsal surface of abdomen medium to dark brown except basal five-sixths yellow. ***Terminalia***. Sternite 8 with 29–35 medium-long to long hairs together with two to four slender short hairs on each side. Ovipositor valves each moderately covered with microsetae interspersed with two or three short hairs; inner margins sinuous. Paraproct in ventral view with four to six sensilla on anteromedial surface; paraproct in lateral view 0.66 times as long as wide, with 20–23 medium-long to long hairs on ventral and lateral surfaces. Cercus in lateral view 0.67 times as long as wide. Spermatheca ellipsoidal, 1.59–1.71 times as long as its greatest width.

Male (n=2). Body length 2.2–2.3 mm. ***Head***. Nearly as wide as thorax. Upper eye medium brown, consisting of large facets in 12 vertical columns and 13 or 14 horizontal rows on each side. Clypeus brownish black, whitish pruinose, densely covered with yellow scale-like medium-long hairs (mostly directed upward) interspersed with several dark brown longer hairs near lower margin on each side. Antenna composed of scape, pedicel and nine flagellomeres, medium to dark brown except scape and pedicel yellow and base of first flagellomere whitish yellow, though apical half of pedicel often light to medium brown; first flagellomere elongate, 1.88–2.10 times length of second. Maxillary palpus light to medium brown, with five segments, proportional lengths of third, fourth, and fifth segments 1.00:1.03–1.06:2.03–2.40; third segment (Figure 3B) slender; sensory vesicle (Figure 3B) small, globular or ellipsoidal (0.17–0.20 times length of third palpal segment), and with small opening. ***Thorax***. Nearly as in female. ***Legs***. Coloration nearly as in female, although appearing incomplete due to pharate condition. Fore basitarsus slightly dilated, 6.67 times as long as its greatest width; hind basitarsus (Figure 3D) slightly widened medially, 5.05 times as long as wide, and 0.67 and 0.62 times as wide as greatest width of tibia and femur, respectively; calcipala (Figure 3D) slightly longer than basal width, and 0.42 times as wide as greatest width of basitarsus. ***Wing***. Length 2.2–2.3 mm. Other characters as in female except subcosta bare. ***Halter*** and ***Abdomen***. Nearly as in male of *S. sachini*. ***Genitalia***. Coxite in ventral view (Figure 3F) nearly rectangular, 1.75 times as long as its greatest width. Style in ventral view (Figure 3F) bent inward, with single apical spine; style in ventrolateral view (Figure 3G) gradually tapered from base to truncated or round apex, 0.88 times length of coxite and 2.43 times as long as its greatest width at base. Ventral plate in ventral view (Figure 3F) with body transverse, 0.51 times as long as wide, widest near base, with anterior margin produced anteromedially, posterior margin gently rounded, and moderately covered with microsetae on ventral surface; basal arms of moderate length, nearly parallel-sided, then somewhat convergent apically; ventral plate in lateral view (Figure 3H) much produced ventrally and somewhat posteriorly; ventral plate in caudal view (Figure 3I) rounded ventrally, moderately covered with microsetae on posterior surface. Median sclerite arising near anterior tip of ventral plate and broad, plate-like in caudal view nearly as in male of *S. sachini*. Paramere (Figure 3J) of moderate size, with three distinct long, three medium-long and several short hooks. Aedeagal membrane nearly as in male of *S. sachini*. Ventral surface of abdominal segment 10 without distinct hairs near posterolateral corners. Cercus small, rounded, with 15 or 16 hairs.

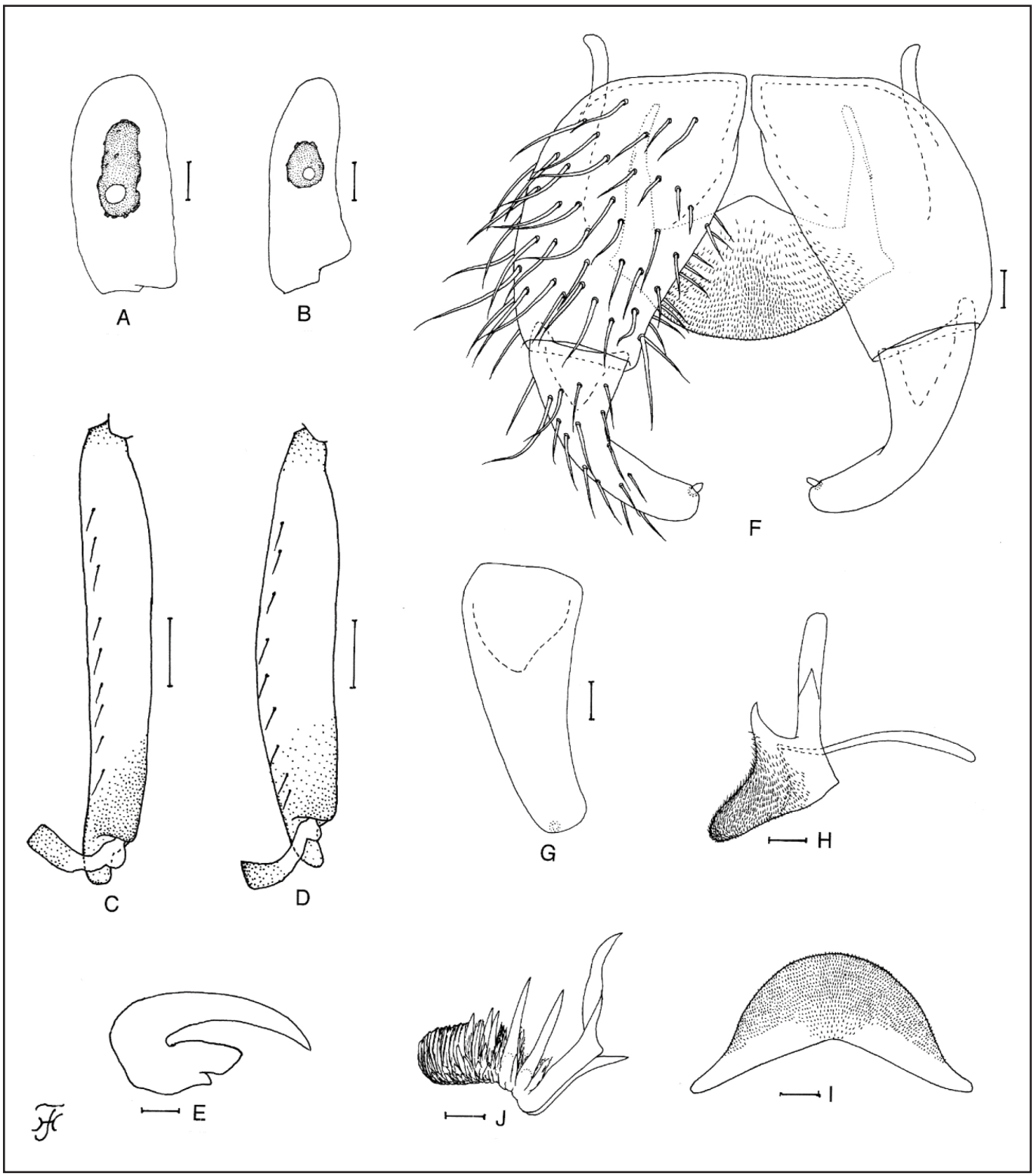

Figure 3. Female and male of *S. williei*. A, C and E female. B, D, F–J male. A and B, sensory vesicles (right side; front view). C and D, hind basitarsi and second tarsomeres (left side; outer view). E, claw. F, coxites, styles and ventral plate (ventral view). G, style (right side; ventrolateral view). H, ventral plate and median sclerite (lateral view). I, ventral plate (caudal view). J, paramere (right side; dorsal view) Scale bars. 0.1 mm for C and D; 0.02 mm for A, B and F–J; 0.01 mm for E.

Remarks. The female of *S. williei* is similar to that of *S. thuathienense* Takaoka & Sofian-Azirun from Vietnam (Takaoka *et al*., 2015) in sharing the medium-long sensory vesicle (Figure 3A), relative length of the fore basitarsus against its greatest width and claw with a large basal tooth (Figure 3E). However, there is a difference in the relative width of the head against the greatest width of the frons (4.0–4.3 in *S. williei* versus 5.2 in *S. thuathienense*).

The male of *S. williei* is characterized by the smaller number of upper-eye (large) facets in 12 vertical columns and 13 or 14 horizontal rows, and ventral plate much produced posteroventrallly when viewed laterally (Figure 3H). *Simulium langkawiense* Takaoka, Sofian-Azirun & Ya'cob from Peninsular Malaysia (Takaoka *et al*., 2013) has the smaller number of male upper-eye (large) facets in 11 or 12 vertical columns and 12 or 13 horizontal rows. However, this species is distinguished from *S. langkawiense* by the shape of the ventral plate, of which the posterior margin is rounded in this species but nearly straight in *S. langkawiense* when viewed ventrally.

Declaration of Competing Interest

We declare that this is our original work. It has not been published elsewhere and we have no conflicts of interest concerning the work reported in this paper. All authors have contributed to this study throughout the study design, field work, data collection, data analyses and data interpretation. The authors have read and approved the manuscript.

ACKNOWLEDGEMENTS

We are grateful to Dr. Peter H. Adler (Professor Emeritus, Clemson University, Clemson, SC, USA) for reading the current manuscript and providing valuable comments. Thanks are due to Dr. M. Fukuda (Oita University, Japan) and Dr. V.L. Low (Universiti Malaya, Malaysia) for their kind help in various ways. We acknowledge funding from the Ministry of Higher Education, Malaysia, under the Higher Institution Centre of Excellence (HICoE) niche area vector and vector-borne diseases (project no. MO002-2019).

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